Appendix G

Summary of Hydraulics and Sedimentation Characteristics

BLASLAND, BOUCK & LEE, INC.
engineers, scientists, economists

Appendix G – Summary of Hydraulics and Sedimentation Characteristics

This appendix summarizes the hydraulics and sedimentation characteristics for Terminal 4. A summary of available current velocity data is provided in Section G.1 and available sediment deposition data are summarized in Section G.2. The information included in this appendix was obtained during the 2004 EE/CA field program and through a review of available meteorological data, historical basin hydrology data, and bathymetric data. A more detailed discussion of hydraulics and sedimentation characteristics and the data collection methods used during the 2004 EE/CA field program is provided in the characterization report (BBL, 2004a).

Additional data related to sediment resuspension and deposition within the Removal Action Area are being collected as part of the ongoing post-Removal Action recontamination analysis. If available, these additional data will be presented in subsequent versions of the EE/CA report.

G.1 Current Velocity

Current velocities within the Removal Action Area were evaluated using cross-sectional velocity measurements obtained for the Willamette River and Slips 1 and 3 on March 25, 2004, and acoustic Doppler current meter (ADCM) data recorded in Slip 3 over three deployment periods in March, April, and May, 2004. Overall, the data indicate that there were little or no river-induced currents observed in the slips during the study period and that current velocities in Slip 3 are dominated by propeller-induced currents. The velocity data are corroborated by the sediment deposition data discussed in Section G.2.

The cross-sectional velocity measurements and the ADCM measurements for Slip 3 are discussed below.

Cross-sectional Velocity Measurements

Cross-sectional velocity measurements were obtained for the Willamette River and Slips 1 and 3 by conducting an acoustic Doppler current profiler (ADCP) survey on March 25, 2004. The survey consisted of more than 60 ADCP track lines run along 14 pre-planned transects (Figures G-1 and G-2). The survey was conducted from high slack water until low slack water as predicted by National Oceanic and Atmospheric Administration (NOAA) tide tables. During the survey, four cycles of each of the 14 track lines were completed. A fifth cycle of the cross-river transect (Track Line 14) was also completed at the end of the survey. The survey was timed to coincide with a spring tide on March 25, 2004. The daily flow of the Willamette River on this date, as recorded by the United States Geological Survey (USGS) gage at Portland, was 24,000 cubic feet per second (cfs). Detailed information related to the ADCP equipment, survey methods, instrument accuracy, track-line coordinates, and starting times is provided in Section 3.5 of the characterization report (BBL, 2004a).

The ADCP measurements provide "snapshots" of the magnitude and direction of flow in the river adjacent to Terminal 4 and within the slips, which were used to evaluate flow and circulation patterns. A high-density of velocity and direction measurements were collected along each transect from the water surface to the mudline. Generally, the survey results indicate a zone of strong currents in the river adjacent to Terminal 4 that are predominantly influenced by river flow and tidal action in the absence of strong winds (Figures G-1 and G-2).

A transition zone between weak and strong currents was evident at the mouths of Slips 1 and 3, and within Wheeler Bay. Currents within the slips were weak and variable, except during periods of vessel activity. Cross-sectional velocity profiles obtained from the ADCP survey are provided in Section 4.5 and Appendix H of the characterization report (BBL, 2004a).

The data indicate little or no current observed in the slips during the one-day survey period, while the observed maximum flow velocity within the Willamette River channel was approximately 1.5 feet per second (during maximum current conditions of the ebb tide). During the relatively low-flow, low-rainfall conditions encountered during the survey period, measurements within the slips were often comparable to the measurement accuracy of the ADCP equipment. Generally, the ADCP data show that the strongest river-induced currents occur along the western edge of the Removal Action Area bordering the main river. The data indicate the presence of a clockwise eddy caused by the river near the mouth of Slip 3. This data is consistent with expectations due to the orientation of the slips relative to the river. The ADCP data also show that secondary eddy currents caused by the river may induce upstream flow in Wheeler Bay.

Acoustic Doppler Current Meter Data

Two Nortek Aquadopp™ acoustic Doppler current meters (ADCMs) were used to measure current velocity and direction at two locations within Slip 3 ("Slip 3 East" and "Slip 3 West") over three deployment periods from March 18 through April 6, 2004, April 6 through April 26, 2004, and April 27 through May 17, 2004. ADCM deployment locations are shown on Figure G-3. The ADCMs were deployed at a height of approximately 1 meter above the river bed and were co-located with sediment traps deployed at the same locations. Detailed information related to the ADCM instrumentation, instrument accuracy, and data logger software is provided in Section 3.5 of the characterization report (BBL, 2004a).

The ADCMs integrate Doppler velocity measurements with data from standard sensors, such as temperature, pressure, tilt, and compass. Data loggers on the ADCMs were programmed to record current meter readings every 10 minutes for a 1-minute period. Measurements collected over the 1-minute period were then averaged. Time-series plots of the ADCM velocity data are provided in Section 4.5 of the characterization report (BBL, 2004a). The velocity measurements were correlated with turbidity data collected using sensors installed on the ADCMs and with vessel activity logs for Slip 3. The data indicate that there were generally no detectable currents within Slip 3 during the study period, excepting occasional velocity spikes that appear to correspond with recorded vessel activity within the area.

The low current velocities recorded under normal conditions (i.e., no vessel activity) are consistent with the results of the ADCP survey discussed above. A comparison of the ADCM data and vessel activity logs indicates that propeller-induced currents cause circulation and increased velocities and turbidity levels extending outside of the paths that ships take in Slip 3. Additionally, the sediment trap data, discussed below in Section G.2 contained interbedded sand and silt layers, possibly reflecting redistribution and transport of sand particles caused by propeller-induced currents. Based on these data, propeller-induced currents are a dominant process affecting hydraulics and sediment redistribution within the Removal Action Area.

G.2 Sediment Deposition

Sediment deposition within the Removal Action Area was evaluated using sediment traps deployed during the 2004 EE/CA field program and a thorough review of the Port of Portland's most recent sedimentation study (Port of Portland, 2002). This evaluation was conducted to support the post-Removal Action recontamination analysis (Section 10 and Appendix K of the EE/CA report) and the detailed analysis of monitored natural recovery (Section 5.1 and Appendix H).

The sediment trap data provide useful information related to sediment resuspension and deposition that occur during low-flow, low-rainfall conditions, and as a result of vessel movement within Terminal 4. Because of unusually dry weather conditions experienced during the sediment trap deployment periods, the data likely do not represent sediment resuspension or deposition that may occur within the area during high-flow, high-rainfall events. To address this potential data gap, additional sediment resuspension and deposition data are being collected as part of the ongoing post-Removal Action recontamination analysis. If available, these additional data will be presented in subsequent versions of the EE/CA report.

Summaries of the sediment trap data and findings of the Port of Portland's sedimentation analysis are provided below.

Sediment Trap Data

Four sediment traps were constructed and deployed within and upstream of the Removal Action Area over two deployment periods. Traps were deployed during the first period from March 18/19, 2004 through April 6/7, 2004. The second deployment period extended from April 26, 2004 through May 17, 2004. Sediment trap deployment locations are shown on Figure G-3. During the first deployment period, one trap was placed near the center of Slip 1 (Slip 1), two traps were placed near the head and mouth of Slip 3 (Slip 3 East and Slip 3 West, respectively), and one trap was located near Berth 414 (Toyota Dolphin). The sediment traps were redeployed at the same locations during the second deployment period, except for the trap at location Slip 3 West, which was relocated upstream of Berth 416 (Berth 416). Details related to the sediment trap design, construction, and deployment methods are provided in Section 3.5 of the characterization report (BBL, 2004a).

Sediment traps provide a measure of suspended particle deposition over time. Due to their configuration and location within the water column, the traps collect finer-grained suspended solids that settle within the area, as opposed to sediment bedload. Bedload is the term used for the movement of larger-grained particles that roll, bounce, wash, etc. over the bottom or in a sediment layer close to the bottom. Observations (Section G.1) indicate a lack of river-induced currents in the Removal Action Area during low-flow conditions. As a result, the bedload transport of sediment to the Removal Action Area is not expected to be significant under low-flow conditions. Additional evaluation of potential river-induced currents under high-flow conditions is now under way.

The sediment trap data collected during the 2004 EE/CA field program provide useful information related to sediment resuspension and deposition that would likely occur during low-flow, low-rainfall conditions, and as a result of vessel movement and moderate rain events within Terminal 4. Because of unusually dry weather conditions experienced during the deployment periods, the data likely do not represent sediment resuspension or deposition that may occur during high-flow, high-rainfall conditions. Additional data related to sediment resuspension and deposition are being collected as part of the ongoing post-Removal Action recontamination analysis. If available, these additional data will be presented in subsequent versions of the EE/CA report.

As described above in Section G.1, during the relatively low-flow, low-rainfall conditions encountered during the field program, current velocities were low within the slips. Current velocity measurements were often comparable to the measurement accuracy of the ADCP and ADCM equipment, with the exception of velocity spikes detected when ships were entering or leaving Slip 3. This data is corroborated by the sediment trap data described below. While river-induced currents likely have an influence on the hydraulics and sedimentation characteristics of the removal action area, the data indicate that current velocities are dominated by propeller-induced currents, even in areas outside of the paths that ships take to and from Terminal 4 berths. The sediment trap data indicate that these propeller-induced currents result in significant resuspension of sediment. The data also indicate that ongoing river-induced sedimentation occurs nearly continuously throughout the Removal Action Area. The periodic redistribution of this material by propeller induced currents likely affects long-term sediment accumulation patterns within the slip.

During sample harvesting, distinct layering of the sediment was observed in some of the traps. In some cases, these layers alternated between fine sand and silt; in other cases, they alternated between darker-colored silt and lighter-colored silt. It is possible that these layers reflect the periodic suspension of fine sands due to ships moving in and out of the active berthing areas at Terminal 4 or the effects of rain events and/or changes in river flow. To evaluate the banding observed in the sediment trap samples, a detailed set of photographs was reviewed to count and describe the layering patterns. The observed banding was then compared to vessel activity records within Terminal 4, water stage measurements, and rainfall data over the duration of the sampling period. Vessel activity records were provided by the Port. Photographs and detailed descriptions of the banding observed in the sediment traps are provided in Section 4.5 of the characterization report (BBL, 2004a). The observed banding is summarized below.

Slip 1

During the first deployment period, a band of darker silt was observed in the Slip 1 sediment trap at the approximate midpoint within a layer of lighter colored silt, suggesting that a loading event may have occurred midway through the sampling period. No vessel activity was recorded for Slip 1 during this period, and it is likely that the observed layering is due to discharges from stormwater outfalls within Slip 1 or changes in river flow related to a three-day rain event on March 24 – 26, 2003.

No visible banding was evident in the sediment trap sample collected from Slip 1 during the second deployment period. No vessel activity, significant rainfall events, or significant variations in river flow were recorded during this period. Sediment collected within this trap during the second deployment period may be representative of ongoing river-induced sedimentation within Slip 1.

Slip 3

During the first deployment period, four layers of sand and four to five layers of silt were observed in the Slip 3 East sediment trap and three layers of sand were observed in the Slip 3 West sediment trap. Ship arrival and departure logs indicate that three ships arrived at, and departed from, Berth 410 during this period. Precipitation records also indicate that a three-day rain event occurred from March 24 to 26, 2004. The vessel activity logs indicate that the banding observed in the Slip 3 West trap and a portion of the banding observed in the Slip 3 East trap may have resulted from vessel activity within the slip. The additional fourth layer observed in the Slip 3 East trap may reflect fine sand deposited from stormwater outfalls discharging from eastern end of Slip 3. Due to the trap locations within Slip 3, the Slip 3 East trap would be expected to exhibit a higher degree of influence from potential stormwater outfalls relative to the Slip 3 West trap.

During the second deployment period, a bottom layer of mostly silt with a relatively thick layer of sand in the middle and a top layer of what appears to be mixed silt and sand were observed in the Slip 3 East trap. A trap was not deployed at the Slip 3 West location during this period. Vessel activity logs indicate that one ship visited Berth 411, located at the east end of Slip 3, during the deployment period. This correlates with the observed banding in the Slip 3 East sample.

Toyota Dolphin

During the first deployment period, banding, consisting of six or seven silt layers, was evident in the sediment trap deployed at the Toyota Dolphin location. This banding suggests variations in sediment transport during the deployment period. Based on available data, it was not possible to draw a direct relationship between the layering observed in this trap and vessel activity within Terminal 4. Vessel activity logs provided by the Port indicate that two ships arrived at, and departed from, Berth 415 (located to the south and upstream of the sediment trap) during the deployment period. Due to its location, this trap may also have been influenced by variations in river flow, nearby stormwater outfalls, or other vessel activity in the area. Precipitation records indicate that a three-day rain event occurred from March 24 to 26, 2004, and streamflow data obtained for the Willamette River from the USGS Stream gage at Portland indicate variations in flow of up to 10,000 cfs during the period.

Due to poor photographic quality, it was not possible to directly interpret photographs taken of the sediment trap sample collected from this location during the second deployment period. Field notes logged at the time of sample harvesting indicate that the samples contained light brown silt with very small amounts of sand mixed throughout. Vessel activity logs provided by the Port indicate one ship arrived at and departed from, Berth 414 and three ships arrived at and departed from Berth 415 during the deployment period. As described above, no significant rainfall events or variations in river flow were observed during this period.

Berth 416

The sediment trap at Berth 416 was only deployed during the second deployment period. During this period, two layers of sand and three layers of silt were apparent in the sediment trap sample vials. Vessel activity logs provided by the Port do not indicate activity at Berth 416 during the deployment period. This sediment trap, which was located within the Willamette River upstream of Berth 416, may have been influenced by barge traffic or other vessel activity in the area. As described above, no significant rainfall events or variations in river flow were observed during this period. However, conclusions related to the observed layering cannot be drawn based on the available data.

Port of Portland Sedimentation Study

In order to evaluate the potential effectiveness of monitored natural recovery within portions of the Removal Action Area and the potential for post-Removal Action Recontamination, the degree of scour or sedimentation occurring within the following subareas was assessed:

- Berth 401;
- Slip 1;
- Slip 1 near the mouth;
- Wheeler Bay;
- Slip 3; and
- North of Berth 414.

The sediment trap data described above provide useful information related to sediment resuspension and deposition that would likely occur during low-flow, low-rainfall conditions, and as a result of vessel movement within Terminal 4. However, the data reflect two "snap-shots" of time during the spring of 2004, and a majority of the traps appeared to be significantly influenced by sediment redistribution due to vessel activity within the slips. As a result, it was not possible to quantify annual deposition rates from the sediment trap data and additional sedimentation data, covering a longer time span, was reviewed.

Available hydrographic survey data for Terminal 4, collected as part of the Port's ongoing maintenance program, were compiled and reviewed by the Port in 2002 (Port of Portland, 2002). Based on a review of the information presented in the sedimentation report, hydrographic survey data collected over the three year period between 1998 and 2001 were selected for use in estimating sedimentation patterns for purposes of the EE/CA. The surveys conducted during this period were annual "condition surveys" completed using a multi-beam scan technique that provides a higher level of accuracy than single-beam scans. There were also no recorded floods or maintenance dredging conducted during this period.

As part of the 2002 sedimentation report (Port of Portland, 2002), the Port produced a series of drawings depicting the changes in riverbed elevation from survey to survey. In Roads software was used to transform the data from each survey into a three-dimensional surface map using triangulation. For the survey data collected between 1998 and 2001, points file data were used to create the surface maps with correct coordinates. Once the surfaces were completed for each survey, the difference in elevations between each set of consecutive surveys was calculated. To illustrate the elevation difference between each set of surfaces, isopach drawings were developed. The isopachs use a color palette to distinguish the magnitude of elevation change between two consecutive surveys.

Based on the isopach drawings provided in the 2002 sedimentation report (Port of Portland, 2002), it is evident that sedimentation did not occur uniformly across the individual subareas. In an attempt to quantify the sedimentation in specific subareas, the Port divided each subarea into regions, focusing on portions of the subareas near active berths. The amount of sedimentation was then calculated as a volume change in cubic yards for each region using the three-dimensional surfaces developed with the In Roads software. The change in volume for a particular region was then divided by the total surface area of that region to estimate an average "infill rate". The infill rate was given a positive value for deposition and a negative value for scour. A tabulation of the average annual infill rates estimated for each subarea between 1998 and 2001 is provided as

Table G-1. It should be noted that although values on Table G-1 are provided to the nearest 0.1 ft, given the high level of uncertainty around the survey data and volume calculations, the values should be considered first order approximations and used only to evaluate general trends. Additionally, the numerical sedimentation rates reported in the 2002 sedimentation report were calculated based on observed sedimentation within a portion of each subarea and no calculations were performed directly for Wheeler Bay or the area north of Berth 414. These values were estimated based on a visual review of the isopach figures.

References

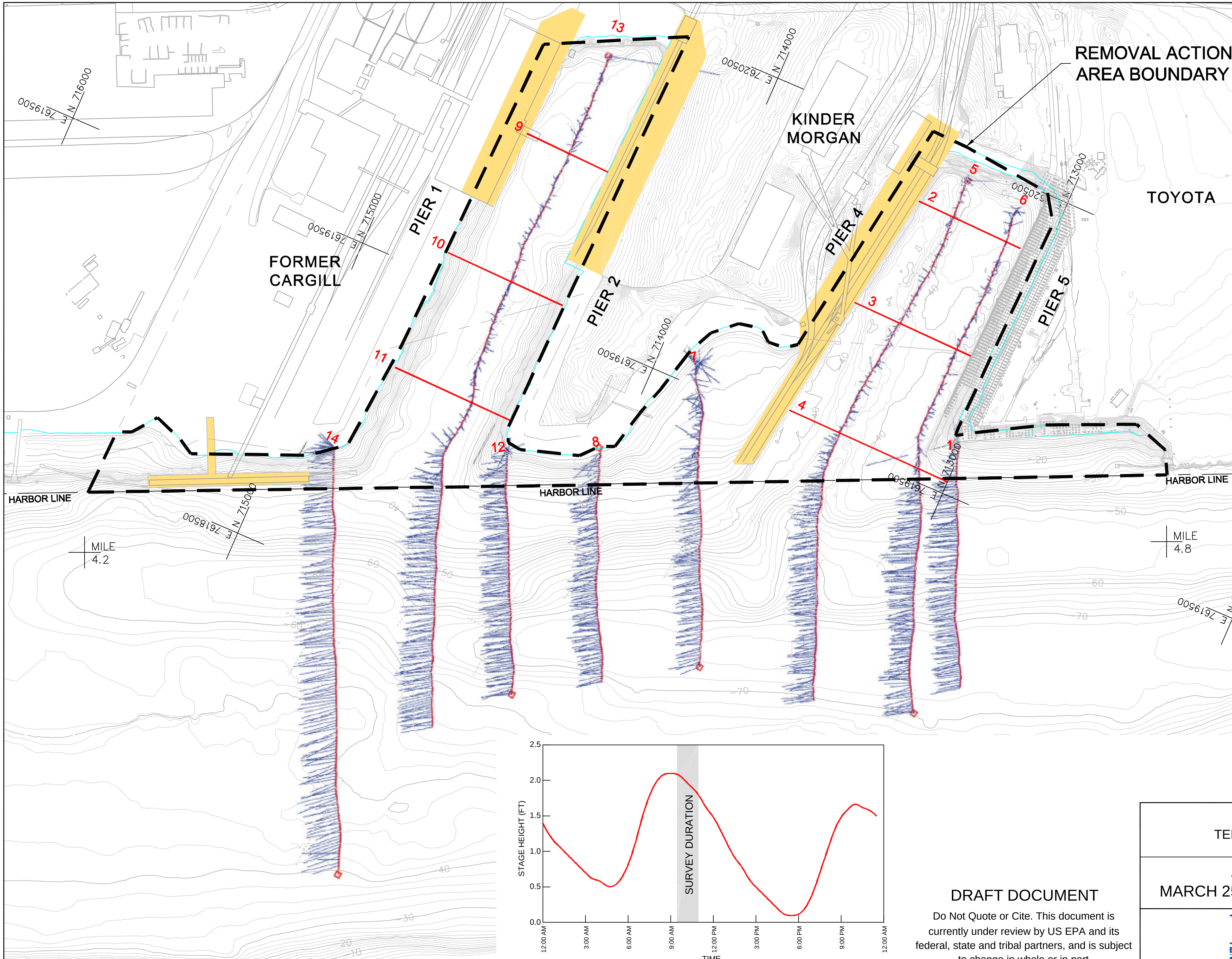
Blasland, Bouck & Lee, Inc. (BBL), 2004a. Characterization Report, Terminal 4 Early Action, Port of Portland, Oregon. September 17.

Port of Portland, 2002. Final Report – Sedimentation at the Port of Portland Terminals. February.

Table G-1
Terminal 4 Sedimentation Analysis Summary[1]
May 1998 through May 2001

Subarea	Estimated Average Sedimentation (ft) May 1998 - June 1999	Estimated Average Sedimentation (ft) June 1999 - June 2000	Estimated Average Sedimentation (ft) June 2000 - May 2001	Estimated Average Sedimentation Rate (ft/yr) May 1998 - May 2001
Berth 401	0.0	0.3	-0.1	0.1
Slip 1	0.0	0.8	0.1	0.3
Slip 1 - Mouth	0.0	0.8	0.2	0.3
Wheeler Bay[2]	0.0	0.8	0.1	0.3
Slip 3	-0.1	0.3	-0.2	0.0
North of Berth 414[3]	0.4	0.5	-0.3	0.2

Notes:
1. Source: Port of Portland, 2002. Final Report – Sedimentation at the Port of Portland Terminals. February.
2. Based on a visual review of the isopach generated of this area for 1999 - 2000, sedimentation in Wheeler Bay was assumed to be similar to sedimentation observed in Slip 1.
3. Based on a visual review of the isopachs generated for this area in 1998 - 2001, sedimentation in this area was assumed to be similar to sedimentation observed near Berth 414.



Existing Piers

Transect Line

No.	Track Line Name
1	Upstream
2	S3_X_East
3	S3_X_Mid
4	S3_X_West
5	S3_A_North
6	S3_A_South
7	WB_A_South
8	WB_A_North
9	S1_X_East
10	S1_X_Mid
11	S1_X_West
12	S1_A_South
13	S1_A_Mid
14	CRT_Downstream

Average Velocity

0 —— 1.5 ft/sec

N

0 300 600

Scale in Feet

Notes:

1. Upland topographic vertical datum is NGVD; Bathymetric vertical datum is CRD.
2. Site Plan is based on drawings provided by the Port of Portland.
3. Shoreline boundary for Ordinary High Water is approximate.
4. Willamette River Mile reference marks are approximate.
5. Diurnal tide range during low river stages is 2.2 feet at St. Johns and 2.4 feet at Portland.
6. Datum conversion tables to CRD provided by Port of Portland.
7. Ordinary Low Water elevation provided by USACE.
8. Ordinary High Water elevation provided by Port of Portland.

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TERMINAL 4 EARLY ACTION
EE/CA REPORT

ADCP TRANSECTS
MARCH 25, 2004 - 9:00AM TO 11:00AM

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FIGURE
G-1

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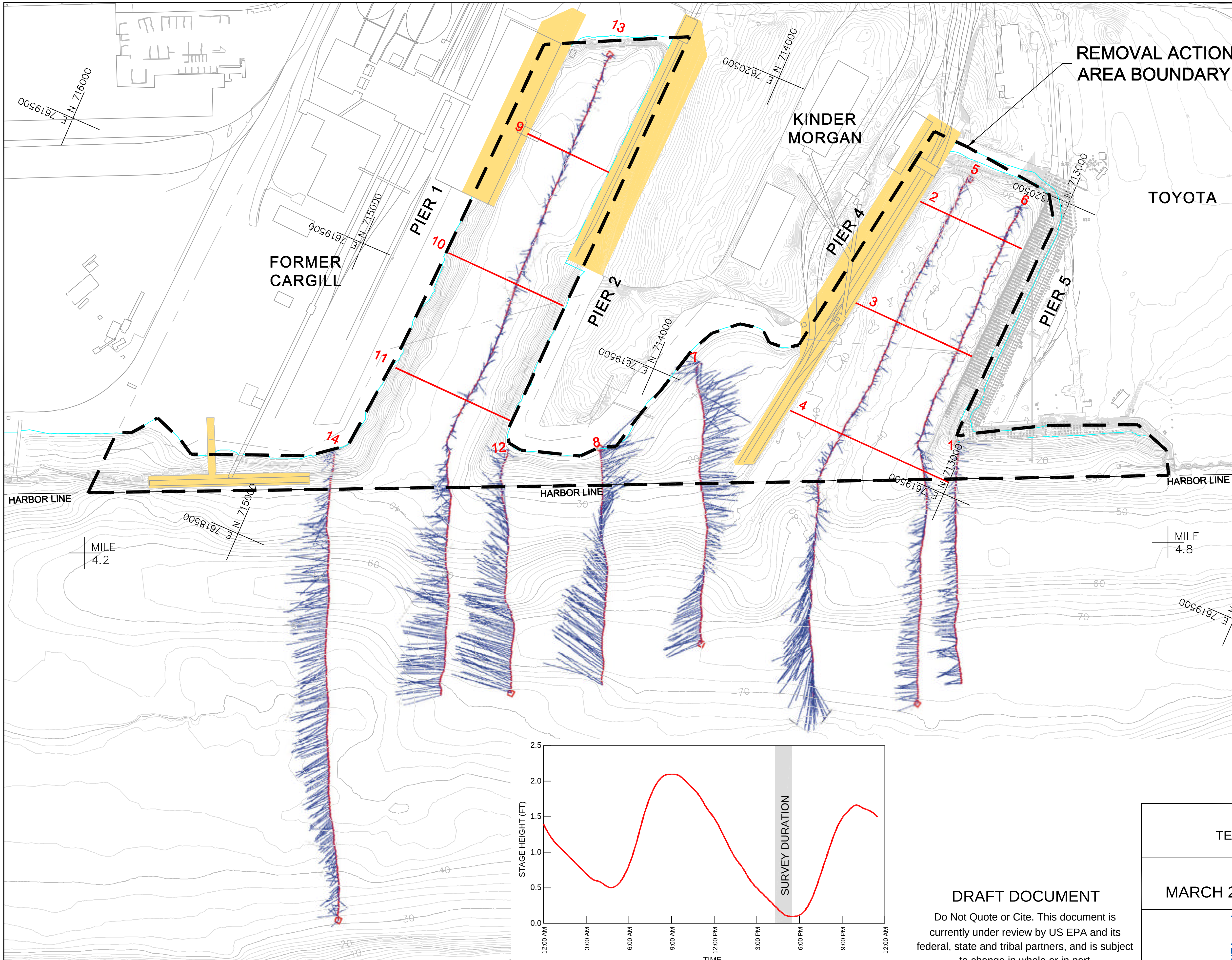
DATE: 01/18/05 12:49pm



Existing Piers

Transect Line

No.	Track Line Name
1	Upstream
2	S3_X_East
3	S3_X_Mid
4	S3_X_West
5	S3_A_North
6	S3_A_South
7	WB_A_South
8	WB_A_North
9	S1_X_East
10	S1_X_Mid
11	S1_X_West
12	S1_A_South
13	S1_A_Mid
14	CRT_Downstream

Average Velocity

0 — 1.5 ft/sec

N

0 300 600

Scale in Feet

Notes:

1. Upland topographic vertical datum is NGVD; Bathymetric vertical datum is CRD.
2. Site Plan is based on drawings provided by the Port of Portland.
3. Shoreline boundary for Ordinary High Water is approximate.
4. Willamette River Mile reference marks are approximate.
5. Diurnal tide range during low river stages is 2.2 feet at St. Johns and 2.4 feet at Portland.
6. Datum conversion tables to CRD provided by Port of Portland.
7. Ordinary Low Water elevation provided by USACE.
8. Ordinary High Water elevation provided by Port of Portland.

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TERMINAL 4 EARLY ACTION
EE/CA REPORT

ADCP TRANSECTS
MARCH 25, 2004 - 4:00PM TO 5:30PM

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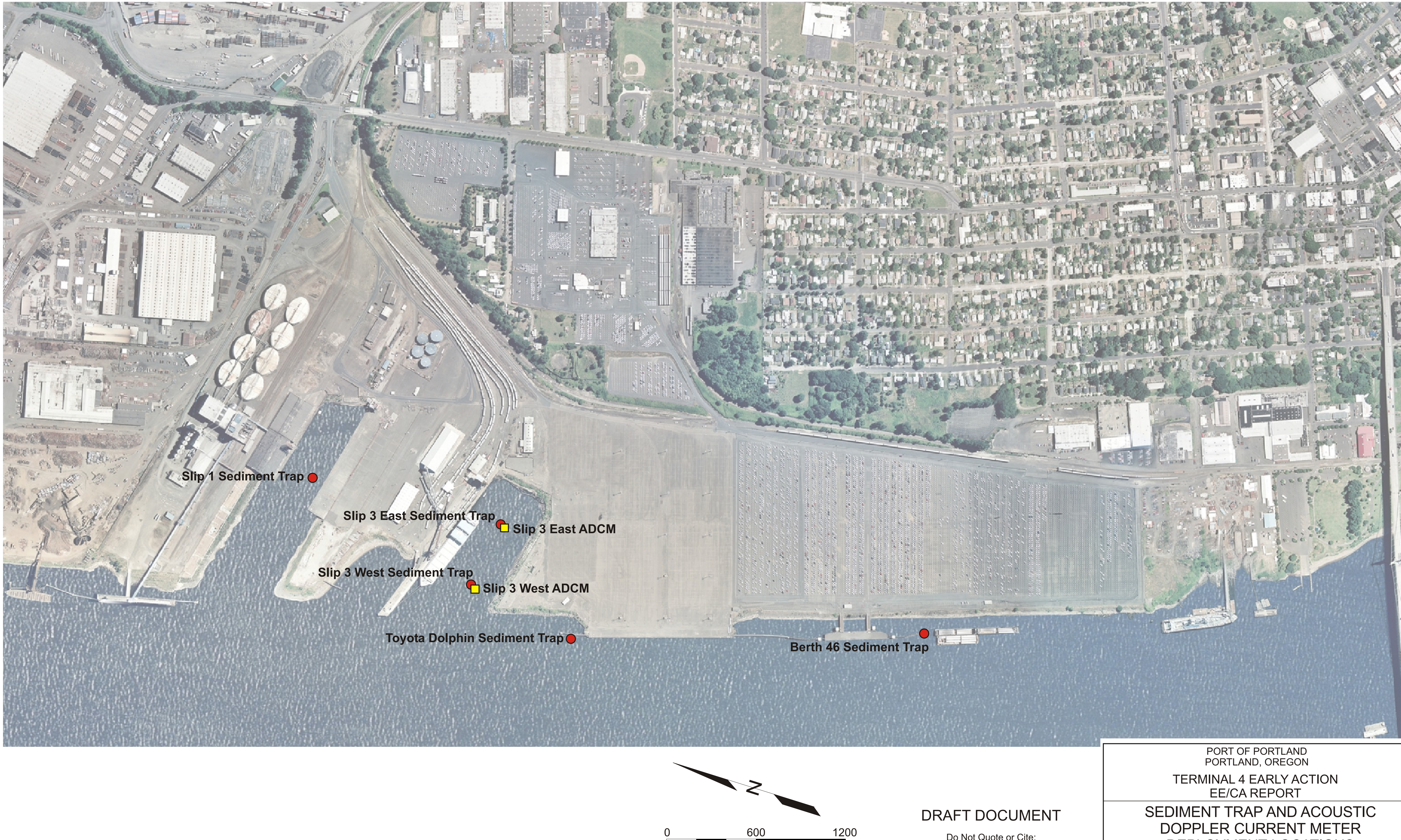
FIGURE
G-2

DWG NAME: G:\project\Clients\BBL\Terminal 4\t4_028 (EECA G-2).dwg
DATE: 01/18/05 12:50pm



Note: Date of Photo: July 9, 2002

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SEDIMENT TRAP AND ACOUSTIC DOPPLER CURRENT METER DEPLOYMENT LOCATIONS

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FIGURE
G-3